Research-Based Principles of Multimedia Training

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3. Theory: How does multimedia learning work?
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   Redundancy principle
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Take-Home Message

ple learn better when multimedia messages are desig
ays that are consistent with how the human mind wo
and with research-based principles.

Three Views of Multimedia

View	Definition	Example
Delivery media	Two or more delivery devices	Computer screen and amplified speakers
Presentation modes	Verbal and pictorial representations	On-screen text and animation
Sensory modalities	Auditory and visual senses	Narration and animation

Two Approaches to Multimedia Design

Approach	Starting point	Goal	Issues
Technology-centered	How can we use access to technology	Capabilities of cutting edge information	Provide multimedia technology in designing multimedia presentations?
Learner-centered	How the human mind works	Aid to human cognition	How can we adapt multimedia technology to aid human

Two Metaphors of Multimedia Learning

Metaphor	Definition	Learner	Teacher	Goal of Media
Information delivery	Adding information to memory	Passive acquisition	provider; act as receiver	
Knowledge construction	Building a coherent mental model	Active sense maker	Cognitive guide; guidance;	Provide cognitive
			vehicle	

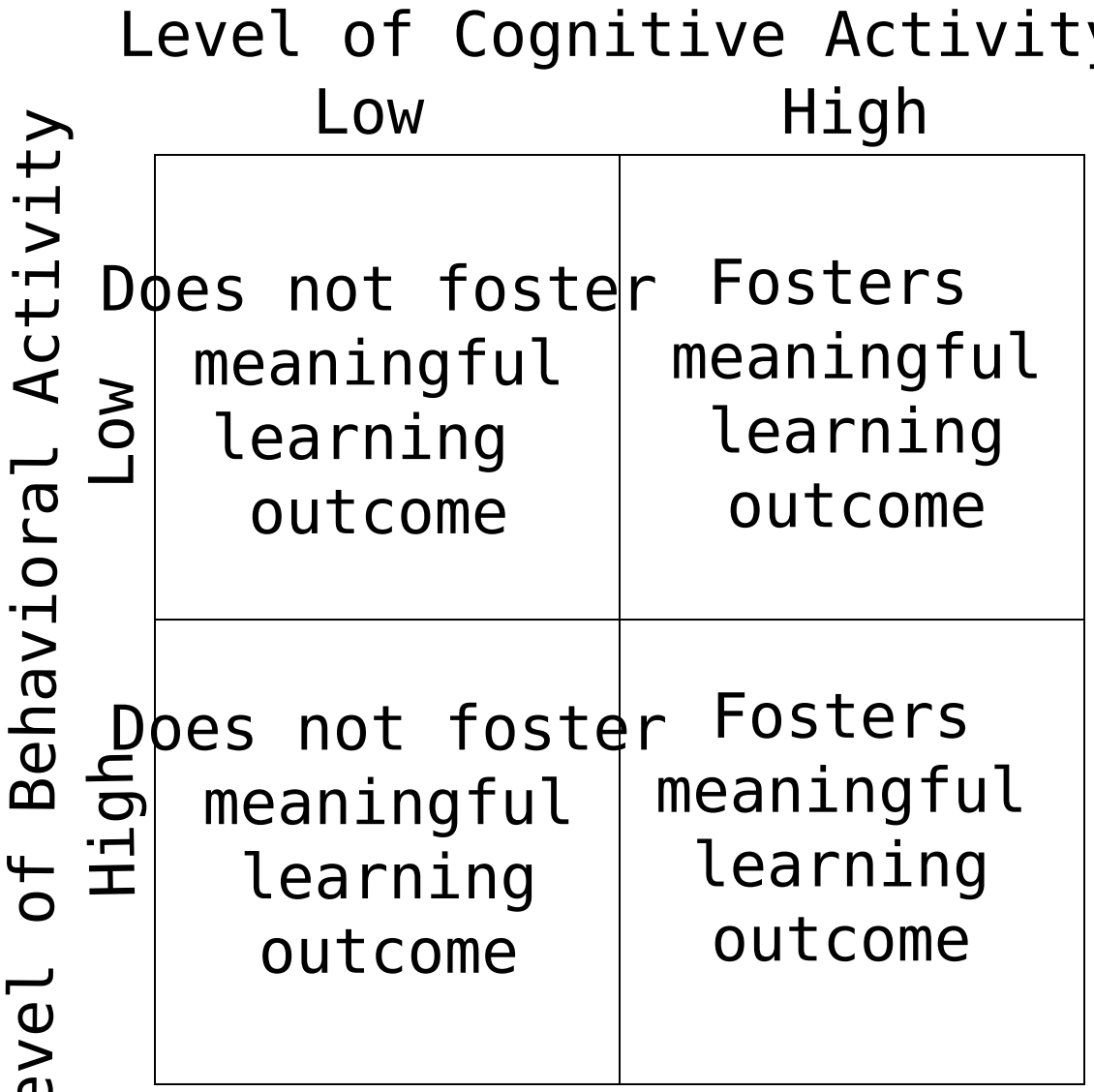
Two Goals of Multimedia Learning

Goal item	Definition	Test	Example test
Remembering	Retention	Ability to reproduce or recognize presented material	Write down all you can remember from the passage you just read.
Understanding Transfer	List some ways to improve the reliability of the device you	Ability to use presented material in novel situations	

Three Kinds of Multimedia Learning Outcomes

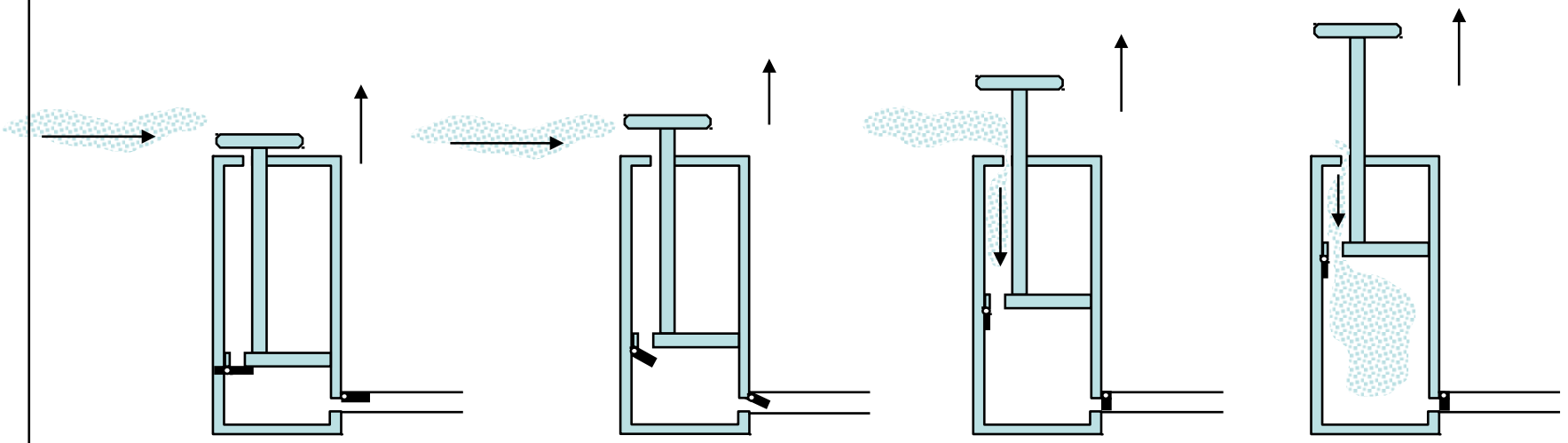
Learning outcome	Cognitive description	Retention test score	Transfer test score
No learning	No knowledge	Poor	Poor
Rote learning	Poor knowledge	Fragmented	Good
Meaningful learning	Integrated knowledge	Good	Good

Two Kinds of Active Learning

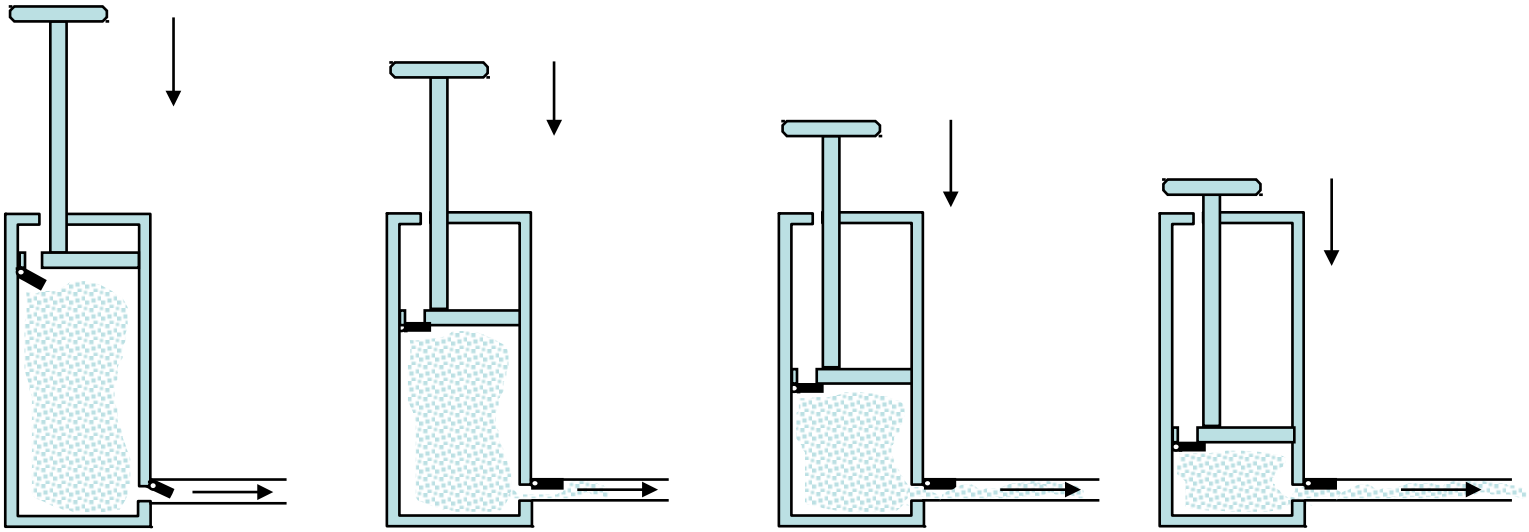


lungs

brakes



“When the handle is pulled up, the piston moves up, the inlet valve opens, the outlet valve closes, and air enters the lower part of the cylinder.”



“When the handle is pushed down, the piston moves down, the inlet valve closes, the outlet valve opens, and air moves out through the hose.”

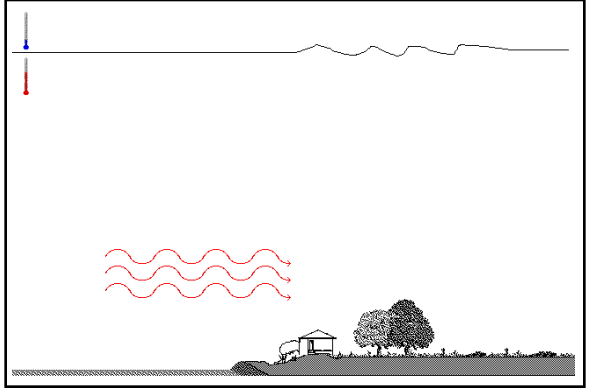
Retention and Transfer Questions for the Pump Lesson

Retention Test

Please write down all you can remember about how a bicycle tire pump works.

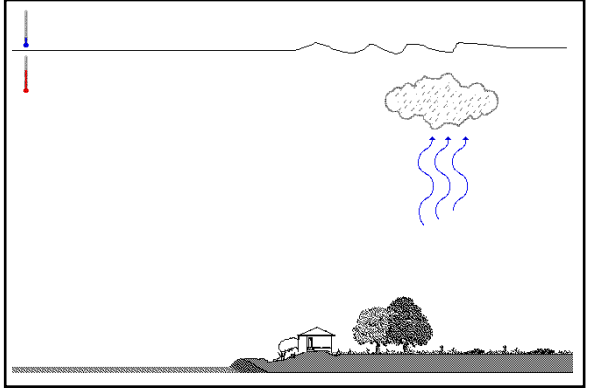
Transfer Test

1. What could be done to make a pump more reliable--that is, to make sure it would not fail?
2. What could be done to make a pump more effect--that is, to make it move more air more rapidly?
3. Suppose you push down and pull up the handle of a pump several times but no air comes out. What could have gone wrong?

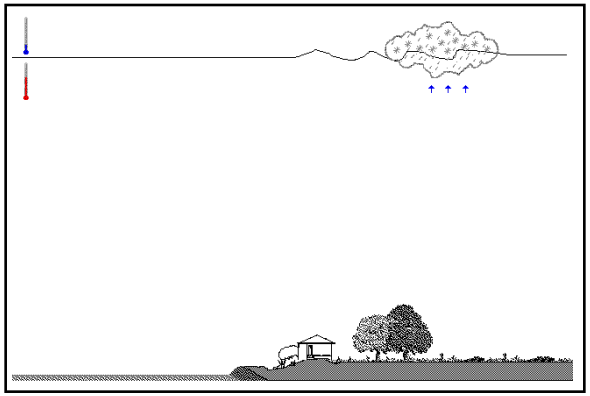


“Cool moist air moves over a warmer surface and becomes heated.”

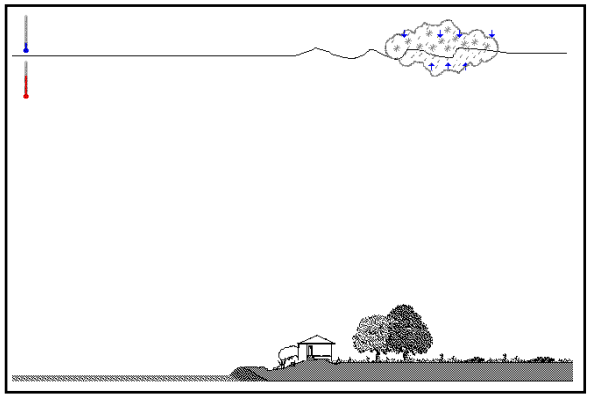
“Warmed moist air near the earth’s surface rises rapidly.”



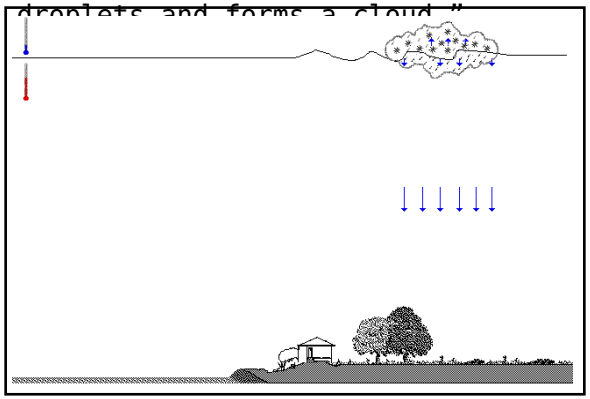
“As the air in this updraft cools, water vapor condenses into water droplets and forms a cloud.”



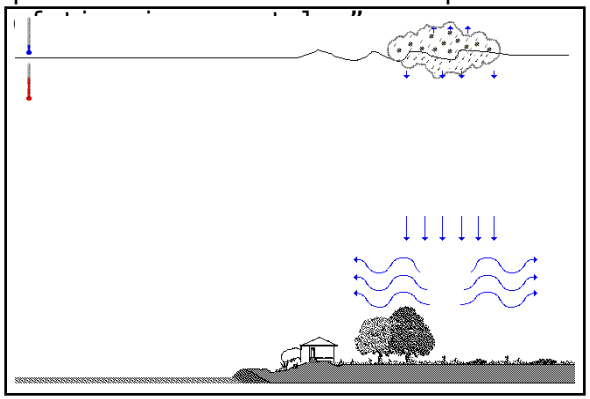
“The cloud’s top extends above the freezing level, so the upper portion of the cloud is composed



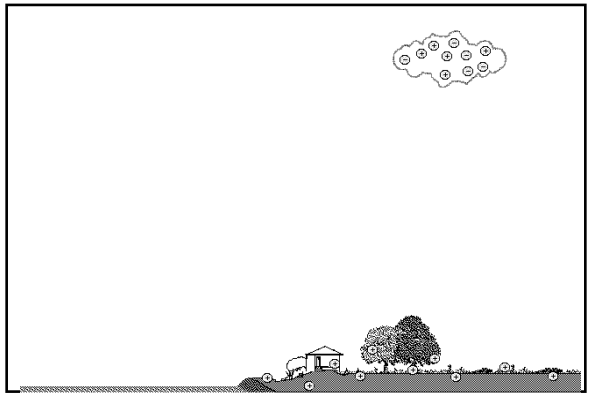
“Eventually, the water droplets and ice crystals become too large to be suspended by the updrafts.”



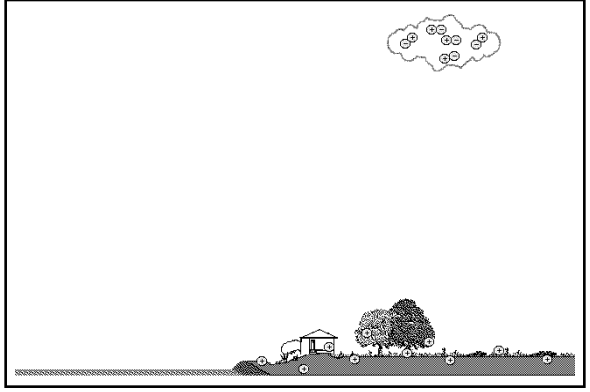
“As raindrops and ice crystals fall through the cloud, they drag some of the air in the cloud downward, producing downdrafts.”



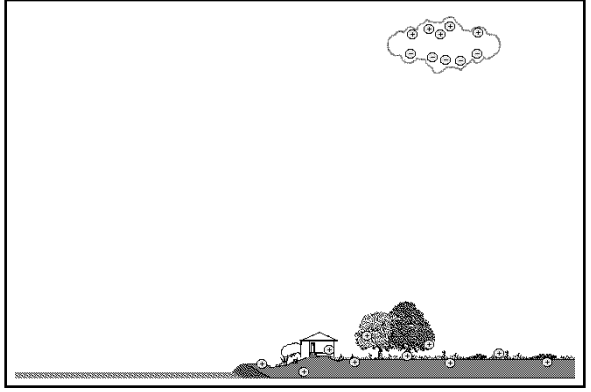
“When downdrafts strike the ground, they spread out in all directions, producing the gusts of cool wind



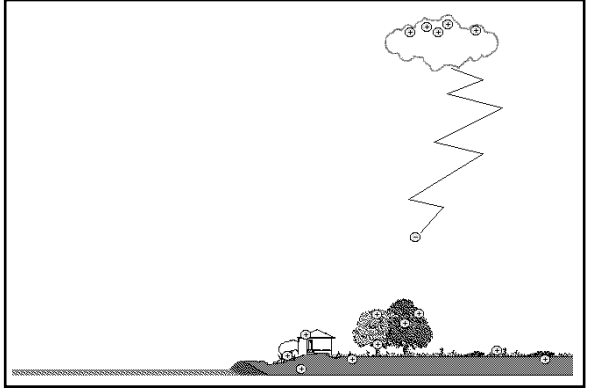
“Within the cloud, the rising and falling air currents cause electrical charges to build.”



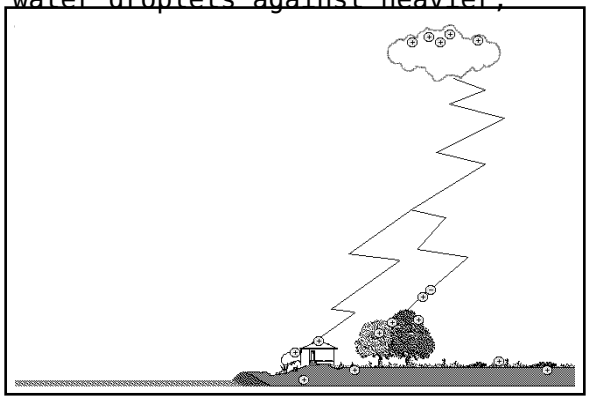
“The charge results from the collision of the cloud’s rising water droplets against heavier,



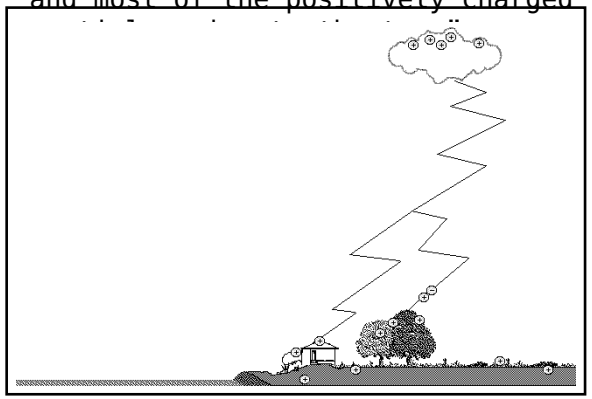
“The negatively charged particles fall to the bottom of the cloud, and most of the positively charged



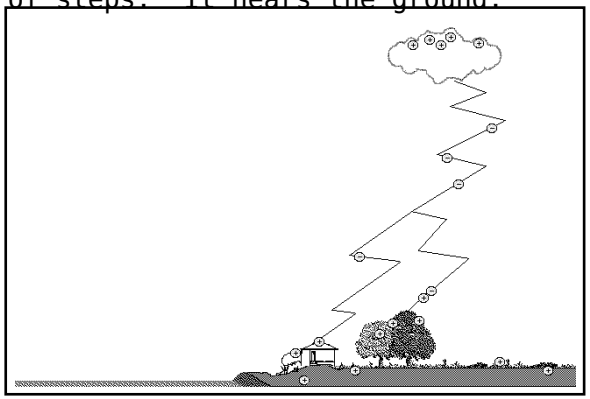
“A stepped leader of negative charges moves downward in a series of steps. It nears the ground.”



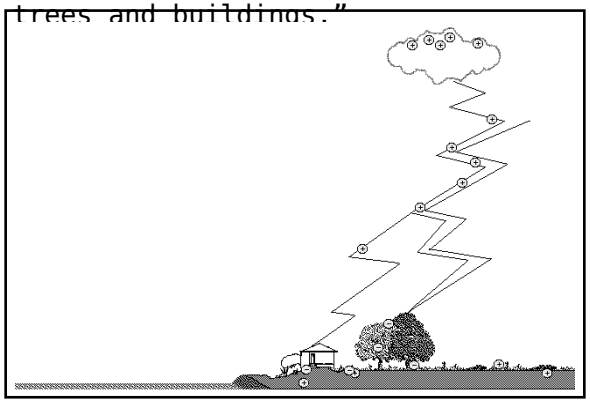
“A positively charged leader travels up from such objects as trees and buildings.”



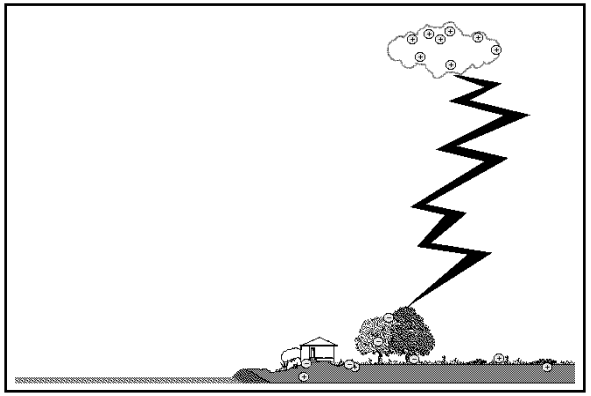
“The two leaders generally meet about 165-feet above the ground.”



“Negatively charged particles then rush from the cloud to the ground along the path created by the leaders. It is not very bright.”



“As the leader stroke nears the ground, it induces an opposite charge, so positively charged



“This upward motion of the current is the return stroke. It produces the bright light that people

Retention and Transfer Questions for the Lightni

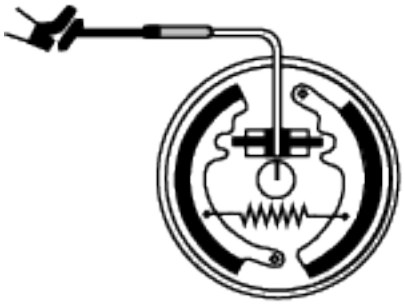
Retention Test

Please write down all you can remember about how

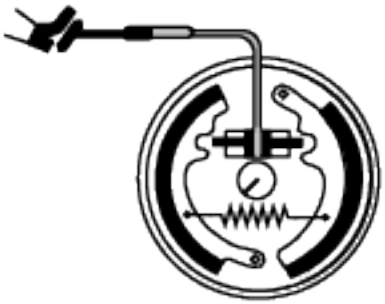
Transfer Test

1. What could you do to reduce the intensity of l
2. Suppose you see clouds in the sky but no light
3. What does air temperature have to do with ligh
4. What causes lightning?

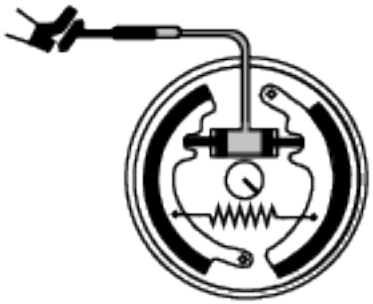
When the driver steps on the car's brake pedal,



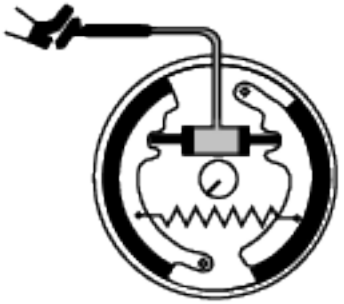
a piston moves forward inside the master cylinder.



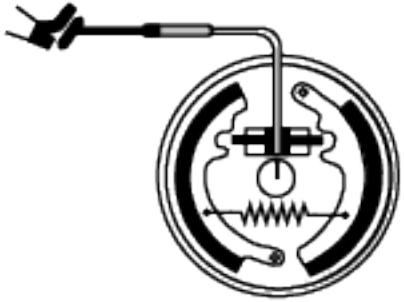
The piston forces brake fluid out of the master cylinder



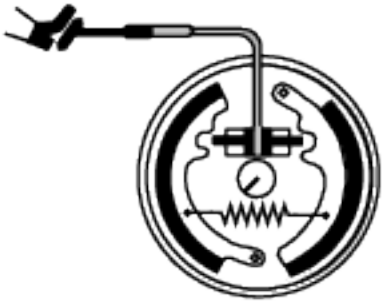
and through the tubes to the wheel cylinders.



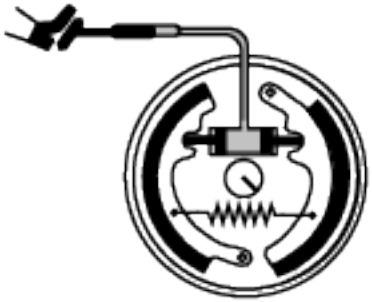
In the wheel cylinders,



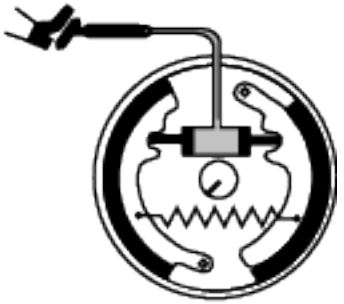
the increase in fluid pressure,



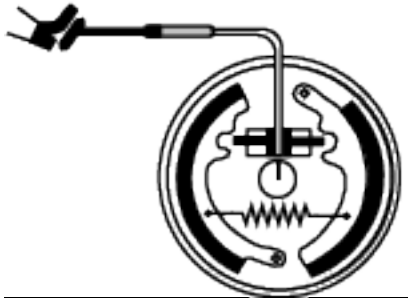
makes a set of smaller pistons move.



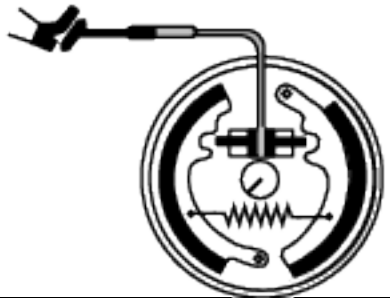
These smaller pistons activate the brake shoes.



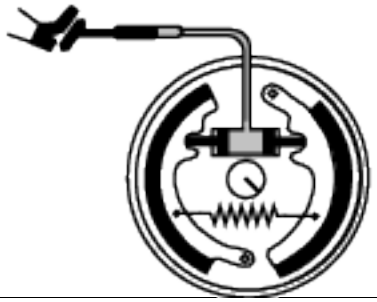
When the brake shoes press against the drum,

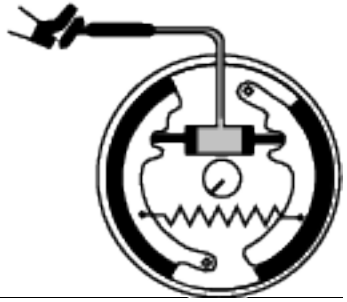


both the drum and the wheel stop



or slow down.





Retention and Transfer Questions for the Brakes Lesson

Retention Test

Please write down all you can remember about how a car's braking system works.

Transfer Test

Why do brakes get hot?

What could be done to make brakes more reliable--that is, to make sure they would not fail?

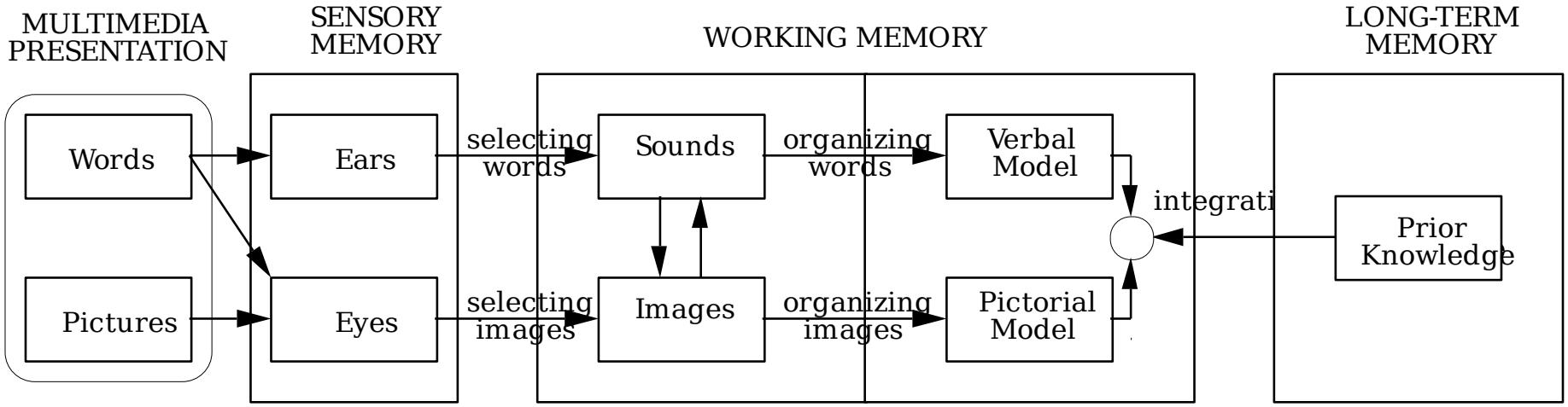
What could be done to make brakes more effective--that is, to reduce the distance needed bring a car to a stop?

Suppose you press on the brake pedal in your car but the brakes

Three Assumptions of a Cognitive Theory of Multimedia Learning

Assumption	Description
Dual channels	Humans possess separate channels for processing visual and auditory information.
Limited capacity	Humans are limited in the amount of information that they can process in each channel at one time.
Active learning	Humans engage in active learning by attending to processing relevant

Cognitive Theory of Multimedia Learning



Five Cognitive Processes for Meaningful Learning

1. Selecting words
2. Selecting images
3. Organizing words
4. Organizing images
5. Integrating

Three Types of Learning Outcomes

Type	Cognitive processing during learning	Retention performance	
No learning	None	Poor	Poor
Rote learning	Selecting	Good	Poor
Meaningful learning	Selecting, organizing and integrating	Good	

Three Demands on Multimedia Learning

Extraneous processing
- Cognitive processing that is not related to
  of the lesson.
- Involves no learning processes.

Essential processing
- Basic cognitive processing that is relevant
  of the lesson.
- Involves selecting and some organizing.

Generative processing
- Deep cognitive processing that is relevant
  of the lesson.
- Involves organizing and integrating.

Reduce Extraneous Processing

Extraneous Processing + Essential Processing + G
Processing Exceeds Cognitive Capacity
Solution: Reduce Extraneous Processing

1. Coherence principle
2. Signaling principle
3. Redundancy principle
4. Spatial contiguity principle
5. Temporal contiguity principle

Cognitive Capacity = Extraneous Processing + Essen
+ Generative Processing

Extraneous Overload

Extraneous processing exhausts cognitive capa
Occurs when lesson contains extraneous materi
designed.

Essential Overload

Essential processing exhausts cognitive capac
Occurs when lesson is difficult, lesson is pr
and the learner is unfamiliar with the materi

Generative Underutilization

Learner has cognitive capacity available but
does not engage in sufficient generative proc
Occurs when learner lacks motivation, does no

Three Ways to Overcome Challenges to Multimedia

1. Reduce extraneous processing
2. Manage essential processing
3. Foster generative processing

Reduce Extraneous Processing

Extraneous Processing + Intrinsic Processing + G
Processing Exceeds Cognitive Capacity
Solution: Reduce Extraneous Processing

1. Coherence principle
2. Signaling principle
3. Redundancy principle
4. Spatial contiguity principle
5. Temporal contiguity principle

Coherence Principle

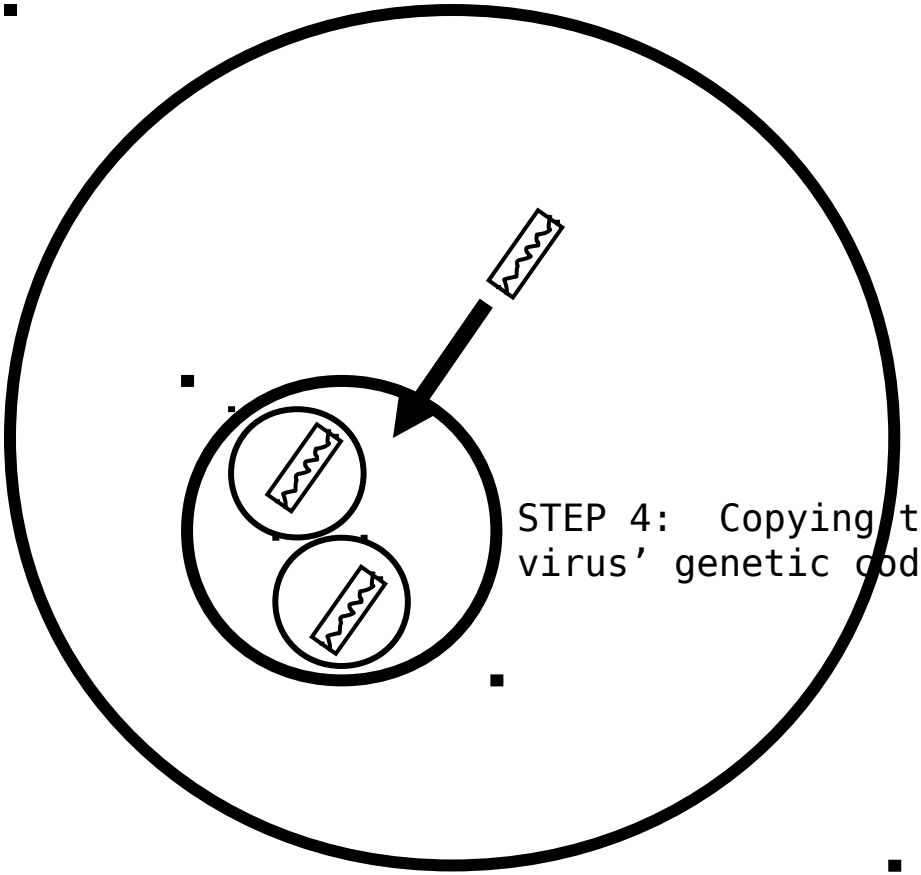
People learn more deeply when extraneous mate
rather than included.

Confirmed in: 11 of 12 tests

Median effect size: 1.13

Step 4: Copying the Virus's Genetic Code

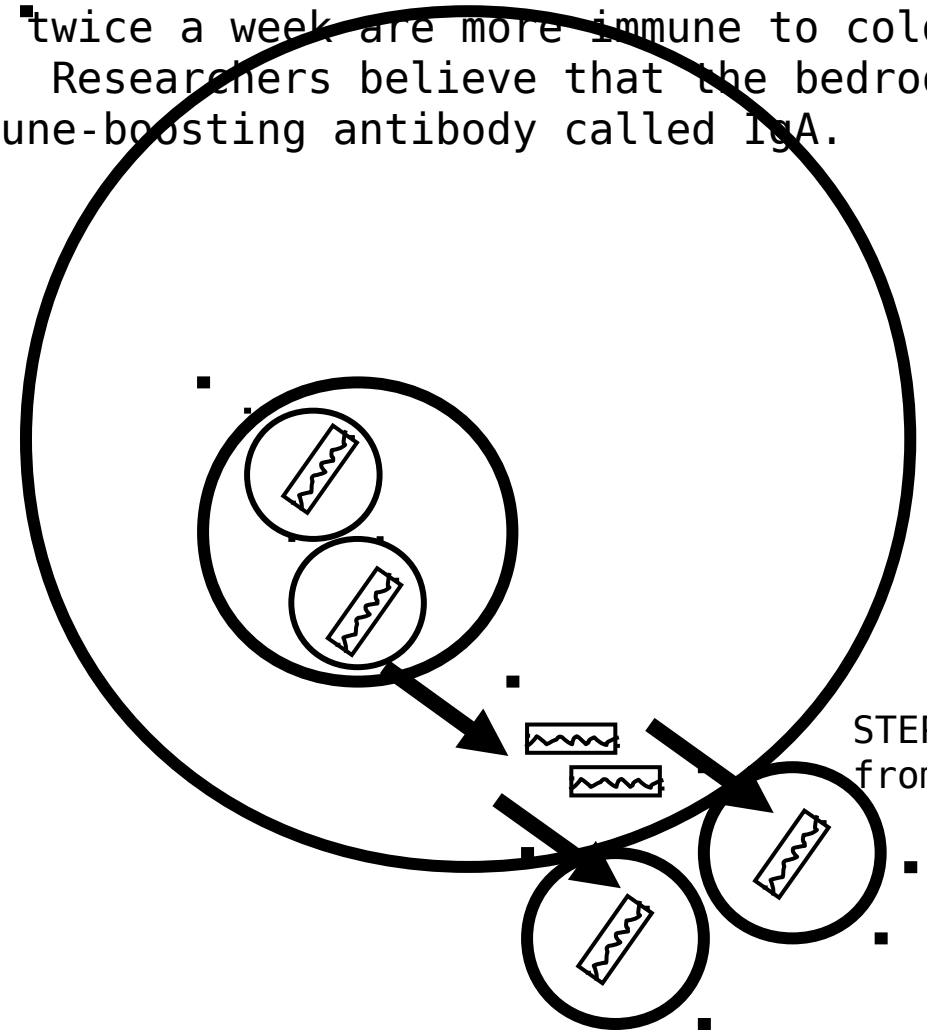
The injected genetic material recruits the host cell's enzymes to help copy the virus's genetic material. Thus, the host cell's enzymes produce parts, such as genetic instructions and proteins, for making more virus particles. The HIV virus is different in every infected person. Some people die soon after getting infected, while others live fairly normal lives for many years, even after they "officially" have AIDS. A few HIV-positive people stay healthy for many years even without taking anti-HIV medications.



STEP 4: Copying the virus' genetic code.

Step 5: Breaking Free from the Host Cell

The new parts are packaged into new virus within the host cell. The new viruses break free from the host cell. In some cases, they break the host cell open, destroying the host cell in the process, which is called lysis. In other cases, they punch out of he cell membrane surrounding them, which is called budding. A study conducted by researchers at Wilkes University in Wilkes-Barre, Pennsylvania, reveals that people who make love once or twice a week are more immune to colds than folks who abstain from sex. Researchers believe that the bedroom activity somehow stimulates an immune-boosting antibody called IgA.



STEP 5: Breaking free from the host cell.

Tests of Coherence Principle

Source	Content	Form	ES
Mayer, Bove et al. (1996, Expt. 1)	lightning	p	
Mayer, Bove et al. (1996, Expt. 2)	lightning	p	
Mayer, Bove et al. (1996. Expt. 3)	lightning	p	
Harp & Mayer (1997, Expt. 1)	lightning	p	1.
Harp & Mayer (1998, Expt. 1)	lightning	p	1.
Harp & Mayer (1998, Expt. 2)	lightning	p	1.
Harp & Mayer (1998, Expt. 3)	lightning	p	1.
Harp & Mayer (1998, Expt. 4)	lightning	p	1.
Moreno & Mayer (2000, Expt. 1)	lightning	c	
Moreno & Mayer (2000, Expt. 2)	brakes		
Mayer, Heiser et al. (2001, Expt. 3)	lightni		
Mayer & Jackson (in press, Expt. 1)	ocean w		
MEDIAN	1.13		

Signaling Principle

People learn more deeply when cues are added tha
the main ideas and organization of the words.

Confirmed in: 3 of 3 tests

Median effect size: 0.60

Examples of Signaled Steps in Lift Lesson

Wing Shape: Curved Upper Surface is Longer

… surface on **top** of the wing is **longer** than

Air Flow: Air Moves Faster Across Top of Wing

…air traveling over the curved **top** of the w
than air that flows under the **bottom** of the

Air Pressure: Pressure on the Top is Less

… the **top** surface of the wing now has **less**
against it than the **bottom** surface of the w

Tests of Signaling Principle

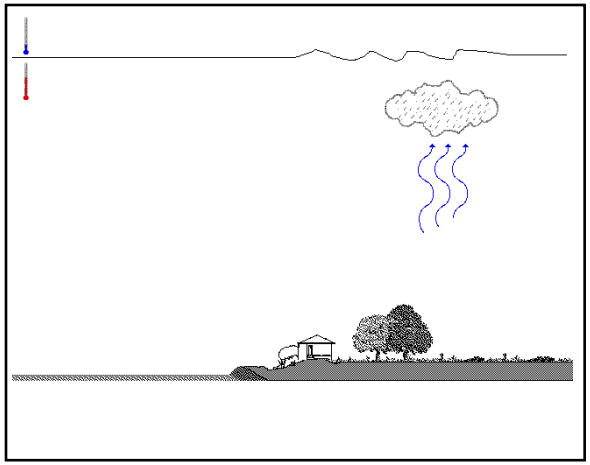
Source	Content	Form	ES
Harp & Mayer (1998, Expt. 3a)	lightning	p	1.
Mautone & Mayer (2001, Expt. 3a)	airplane	lif	
Mautone & Mayer (2001, Expt. 3b)	airplane	lif	
MEDIAN		0.60	

Redundancy Principle:
People learn more deeply from animation and narration than
from animation, narration, and on-screen text.

Confirmed in: 10 of 10 tests

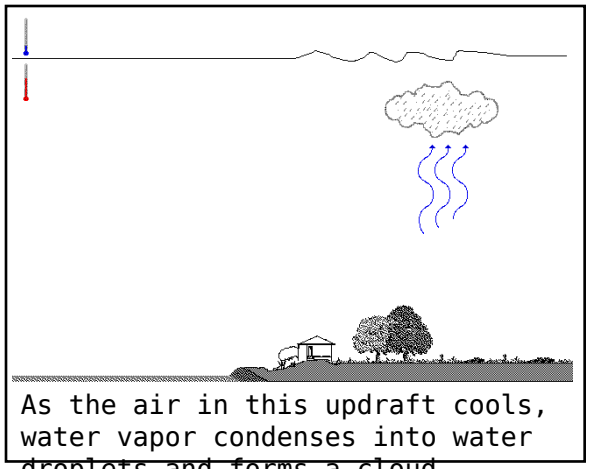
Median effect size: 0.69

Animation and Narration



“As the air in this updraft cools, water vapor condenses into water droplets and forms a cloud”.

Animation, Narration, and On-Screen Text



“As the air in this updraft cools, water vapor condenses into water droplets and forms a cloud”.

Tests of Redundancy Principle

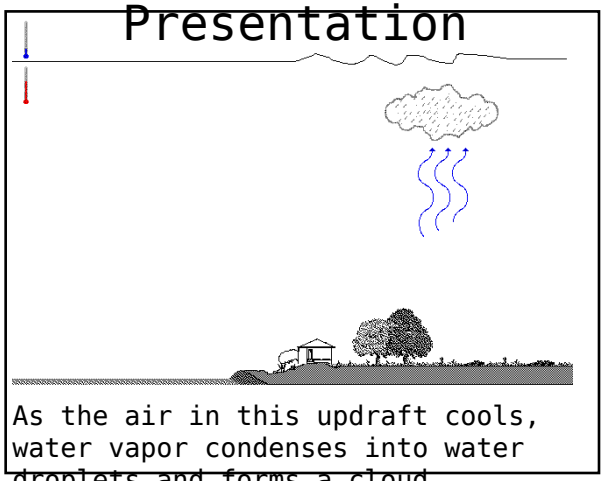
Source	Content	Form	ES
Mousavi, Low et al. (1995, Expt. 1)		math pr	
Mousavi, Low et al. (1995, Expt. 1)		math pr	
Kalyuga et al. (1999, Expt. 1)		enginee	
Kalyuga et al. (2000, Expt. 1)		enginee	
Craig, Gholson et al. (2002, Expt. 2)		lightni	
Mayer, Heiser et al. (2001, Expt. 1)		lightni	
Mayer, Heiser et al. (2001, Expt. 2)		lightni	
Moreno & Mayer (2002b, Expt. 2)	lightning		
Moreno & Mayer (2002a, Expt. 2a)	botany game		
Moreno & Mayer (2002a, Expt. 2b)	botany game		
MEDIAN		0.69	

Spatial Contiguity Principle:
People learn more deeply when corresponding printed words and graphics are placed near rather than far from each other on the page or screen.

Confirmed in: 8 of 8 tests

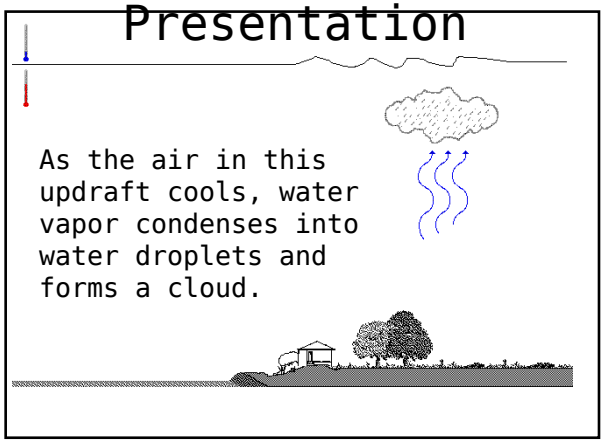
Median effect size: 1.11

Separated Presentation



As the air in this updraft cools, water vapor condenses into water droplets and forms a cloud.

Integrated Presentation



Tests of Spatial Contiguity Principle

Source	Content	Form	ES
Mayer (1989)	brakes		
Sweller et al. (1990, Expt. 1)		math pr	
Chandler & Sweller (1991, Expt. 1)	engineering		
Mayer et al. (1995, Expt. 1)	lightning		
Mayer et al. (1995, Expt. 2)	lightning		
Mayer et al. (1995, Expt. 3)	lightning		
Tinsdall-Ford et al. (1997, Expt. 1)		enginee	
Moreno & Mayer (1999, Expt. 1)	lightning		
MEDIAN		1.11	

Temporal Contiguity Principle:

ple learn more deeply when corresponding graphics
on are presented simultaneously rather than succes

Confirmed in: 8 of 8 tests

Median effect size: 1.31

Tests of Temporal Contiguity Principle

Source	Content	Form	ES
Mayer & Anderson (1991, Expt. 1)	pump		c
Mayer & Anderson (1991, Expt. 2a)	pump		c
Mayer & Anderson (1992, Expt. 1)	pump		c
Mayer & Anderson (1992, Expt. 2)	brakes		
Mayer & Sims (1994, Expt. 1)	pump	c	0.
Mayer & Sims (1994, Expt. 2)	lungs		c
Mayer, Moreno et al. (1999, Expt. 1)		lightni	
Mayer, Moreno et al. (1999, Expt. 2)		brakes	
MEDIAN		1.31	

Manage Essential Processing

roblem: Essential Processing + Generative Processi
Exceeds Cognitive Capacity
Solution: Manage Essential Processing

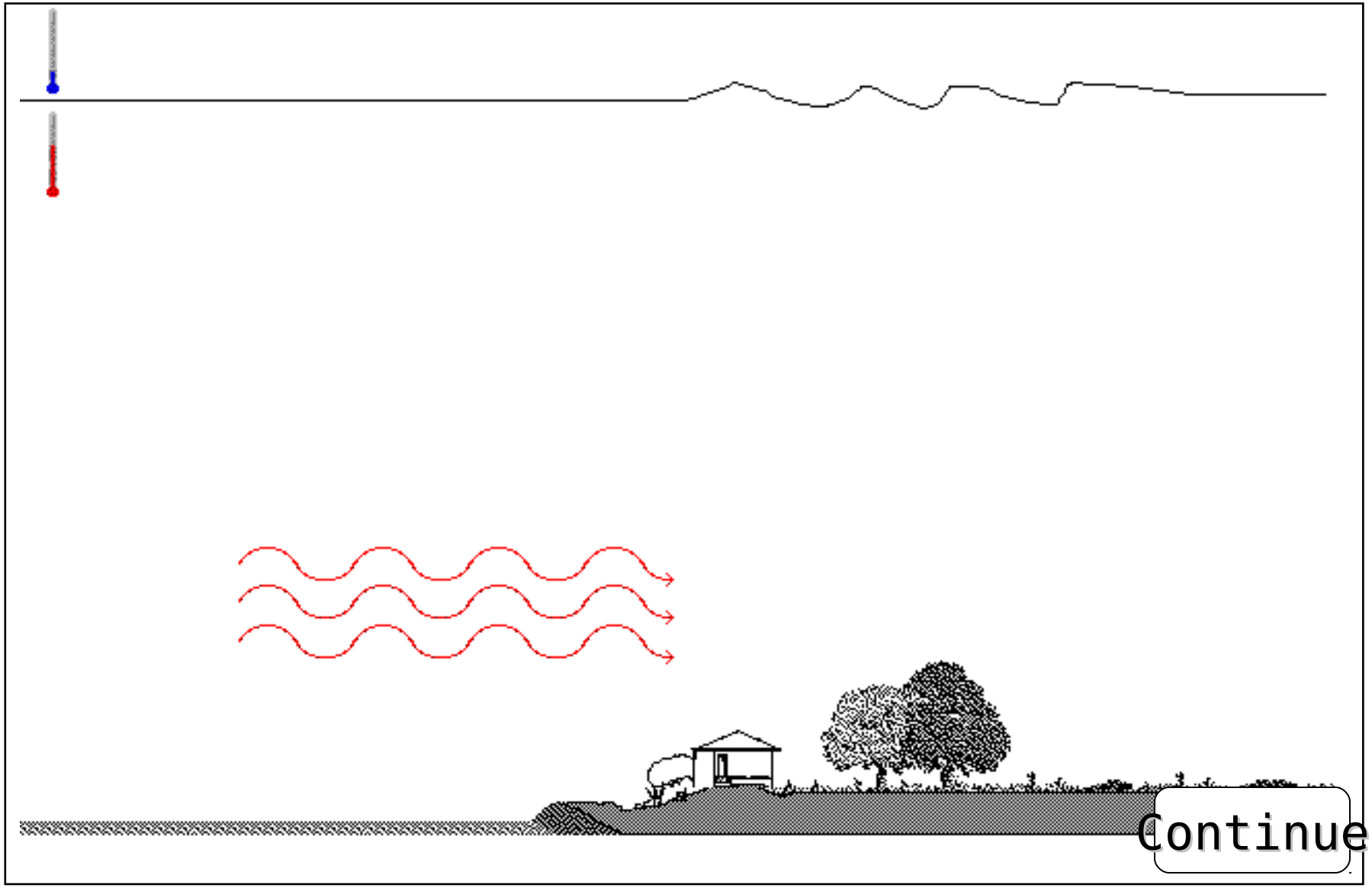
1. Segmenting principle
2. Pre-training principle
3. Modality principle

Segmenting Principle:

learn more deeply when a narrated animation is pr
n learner-paced segments than as a continuous unit

Confirmed in: 3 of 3 tests

Median effect size: 0.98



oist air moves over a warmer surface and becomes h

Tests of Segmenting Principle

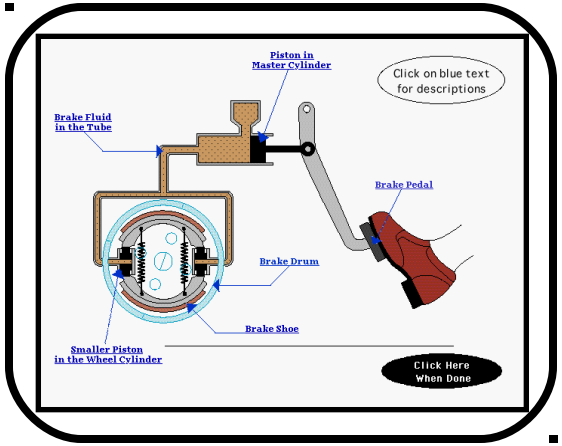
Source	Content	Form	ES
Mayer & Chandler (2001, Expt. 2)	lightning	c	
Mayer, Dow et al. (2003, Expt. 2a)	electric mot		
Mayer, Dow et al. (2003, Expt. 2b)	electric mot		
MEDIAN		0.98	

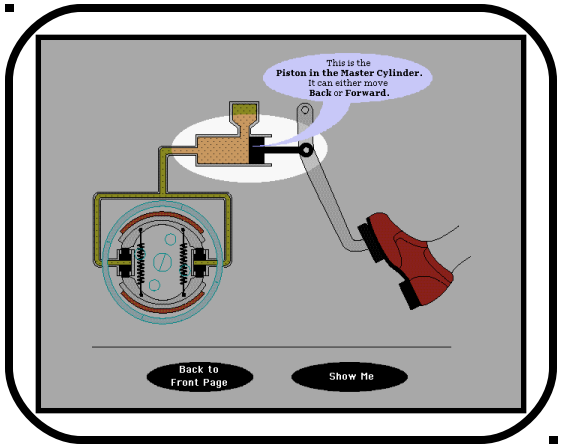
Pre-training Principle:

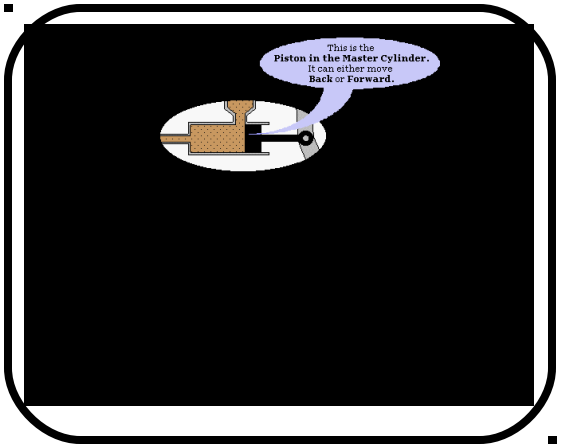
learn more deeply from a narrated animation when th
ning in the names and characteristics of the main c

Confirmed in: 7 of 7 tests

Median effect size: 0.92


Piston in Master Cylinder
Click on blue text for descriptions
Brake Fluid in the Tube
Brake Pedal
Brake Drum
Brake Shoe
Smaller Piston in the Wheel Cylinder
Click Here When Done


This is the Piston in the Master Cylinder. It can either move Back or Forward.
Back to Front Page
Show Me


This is the Piston in the Master Cylinder. It can either move Back or Forward.

Tests of Pre-training Principle

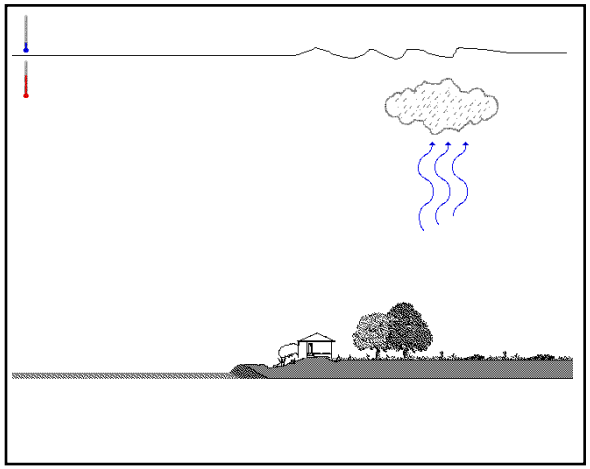
Source	Content	Form	ES
Pollack et al. (2002, Expt. 1)			engine
Pollack et al. (2002, Expt. 3)			engine
Mayer, Mathias et al. (2002, Expt. 1)			brakes
Mayer, Mathias et al. (2002, Expt. 2)			brakes
Mayer, Mathias et al. (2002, Expt. 3)			pump
Mayer, Mautone et al. (2002, Expt. 2)			geology ga
Mayer, Mautone et al. (2002, Expt. 3)			geology ga
MEDIAN			0.92

Modality Principle:
People learn more deeply from graphics and narration than from graphics and on-screen text.

Confirmed in: 21 of 21 tests

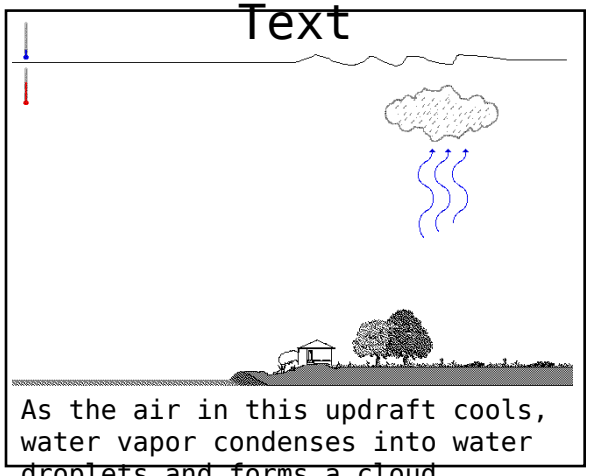
Median effect size: 0.97

Words as Narration



“As the air in this updraft cools, water vapor condenses into water droplets and forms a cloud.”

Words as On-Screen Text



Tests of Modality Principle

Source	Content	Form	ES
Jeung et al. (1997, Expt. 1)	math	problem	
Jeung et al. (1997, Expt. 2)	math	problem	
Jeung et al. (1997, Expt. 3)	math	problem	
Mayer & Moreno (1998, Expt. 1)	lightning		
Mayer & Moreno (1998, Expt. 2)	lightning		
Kalyuga et al. (1999, Expt. 1)		enginee	
Moreno & Mayer (1999b, Expt. 1)	lightning		
Moreno & Mayer (1999b, Expt. 1)	lightning		
Kalyuga et al. (2000, Expt. 1)		enginee	
O'Neil, Mayer et al. (2000, Expt. 1)		aircraf	
Moreno et al. (2001, Expt. 4a)	botany game		
Moreno et al. (2001, Expt. 4b)	botany game		
Moreno et al. (2001, Expt. 5a)	botany game		
Moreno et al. (2001, Expt. 5b)	botany game		
Craig, Gholson et al. (2002, Expt. 2)		lightni	

Tests of Modality Principle (Continued)

Source	Content	Form	ES
Moreno & Mayer (2002, Expt. 1a)	botany game		
Moreno & Mayer (2002, Expt. 1b)	botany game		
Moreno & Mayer (2002, Expt. 1c)	botany game		
Moreno & Mayer (2002, Expt. 2a)	botany game		
Moreno & Mayer (2002, Expt. 2b)	botany game		
Mayer, Dow et al. (2002, Expt. 1a)	electric mot		
MEDIAN		0.97	

Foster Generative Processing

Problem: Insufficient Generative Processing Althou
Cognitive Capacity is Available
Solution: Foster Generative Processing

1. Personalization principle
2. Voice principle

Personalization Principle:
learn more deeply when words are in conversational
rather than formal style.

Confirmed in: 10 of 10 tests

Median effect size: 1.30

Examples of Personalized and Non-Personalized Speech

Non-Personalized

"During inhaling, the diaphragm moves down creating more space for the lungs, air enters through the nose or mouth, moves down through the throat and bronchial tubes to tiny air sacs in the lungs…"

Personalized

"During inhaling, your diaphragm moves down creating more space for your lungs, air enters through your nose or mouth, moves down through your throat and bronchial tubes to tiny air sacs in your lungs…"

Tests of Personalization Principle

Source	Content	Form	ES
Moreno & Mayer (2000, Expt. 1)	lightning c		
Moreno & Mayer (2000, Expt. 2)	lightning c		
Moreno & Mayer (2000, Expt. 3)	botany game		
Moreno & Mayer (2000, Expt. 4)	botany game		
Moreno & Mayer (2000, Expt. 5)	botany game		
Moreno & Mayer (2004, Expt. 1a)	botany game		
Moreno & Mayer (2000, Expt. 1b)	botany game		
Mayer, Fennell et al. (2004, Expt. 1)		lungs	
Mayer, Fennell et al. (2004, Expt. 1)		lungs	
Mayer, Fennell et al. (2004, Expt. 1)		lungs	
MEDIAN		0.97	

Voice Principle:

learn more deeply when the narration is spoken in
dard-accented human voice than a machine voice or
foreign-accented human voice.

Confirmed in: 4 of 4 tests

Median effect size: 0.79

Tests of Voice Principle

Source	Content	Form	ES
Mayer, Sobko et al. (2003, Expt 1)	lightning		
Mayer, Sobko et al. (2003, Expt. 2)	lightnin		
Atkinson, Mayer et al. (2004, Expt 1)	math probl		
Atkinson, Mayer et al. (2004, Expt. 2)	math probl		
MEDIAN		0.79	

Summary of Research Evidence

Principle	Median ES (*d*)	Tests
Coherence	1.13	11 of 12
Signaling	0.60	3 of 3
Redundancy	0.69	10 of 10
Spatial Contiguity	1.11	8 of 8
Temporal Contiguity	1.31	8 of 8
Segmenting	0.98	3 of 3
Pre-training	0.92	7 of 7
Modality	0.97	21 of 21
Personalization	1.30	10 of 10
Voice	0.79	4 of 4

Research-Based Principles for the Design of Multimedia Messages

Coherence principle: People learn more deeply when extraneous words, pictures, or sounds are excluded rather than included. (11 of 12; ES = 1.13)

Signaling principle: People learn more deeply when cues are added that highlight the main ideas and the organization of the words. (3 of 3; ES = 0.60)

Redundancy principle: People learn more deeply from animation and narration than from animation, narration, and on on-screen text. (10 of 10; ES = 0.69)

Spatial contiguity principle: People learn more deeply when corresponding words and pictures are presented near rather than far from each other on the page or screen. (8 of 8; ES = 1.11)

Segmenting principle: People learn more deeply when a narrated animation is presented in learner-paced segments than as a continuous unit. (3 of 3; ES 0.98)

Pre-training principle: People learn more deeply from a narrated animation when they have had training in the names and characteristics of the main concepts. (7 of 7; ES = 0.92)

Modality principle: People learn more deeply from graphocs and narration than from graphics and on-screen text. (21 of 21; ES = 0.97)

Personalization principle: People learn more deeply when the words are in conversational style rather than formal style (10 of 10; ES = 1.30)

Conclusions About the Design of Multimedia Learning

1. Theory-based. The design of multimedia messages should be based on a theory of how the human mind works.
2. Research-based. The design of multimedia messages should be based on research findings.

Bottom line: People learn better when multimedia messages are designed in ways that are consistent with how the human mind works and with research-based principles.

Suggested Readings

Mayer, R. E. (2001). *Multimedia learning.* New York: Cambridge University Press.

Clark, R. C., & Mayer, R. E. (2003). *E-learning and the science of instruction.* San Francisco: J

Mayer, R. E. (2003). *Learning and instruction.* Upper Saddle River. NJ: Prentice Hall.

Mayer, R. E. (Ed.). (2005). *Cambridge handbook of learning.* New York: Cambridge University Pre

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